THE WATCH AS A GROWTH OF INVENTION.

WATCHES made their appearance in Europe about the close of the fifteenth century, and, although our knowledge of their origin is very indefinite, yet they are commonly supposed to have been first made by Peter Hele, of Nuremberg, twenty-five years before the discovery of America. But they were not called *watches;* they were first named from their appearance, and known as *Nuremberg Animated Eggs*. There was almost a prophetic significance in this term, for the Nuremberg egg was the germ of a mechanism and of an industry which have been growing for four hundred years, and have reached their last and highest stage of development only in the present generation.

The watch, like the man who wears it, has a twofold nature, ideal and material—a soul and a body. As man was first a spiritual image, and then a corporeal embodiment, so the watch was first a thought and then a reality; invention created it ideally; industry produces it actually. But both invention and industry are growths of time, and proceed by law. In both there is an orderly progress—infancy, youth, maturity—one stage preparing for another, and each step occurring only in its proper sequence. We propose now to consider the watch from this point of view—in the present article as a growth of thought, and in a subsequent one as a product of progressive industry.

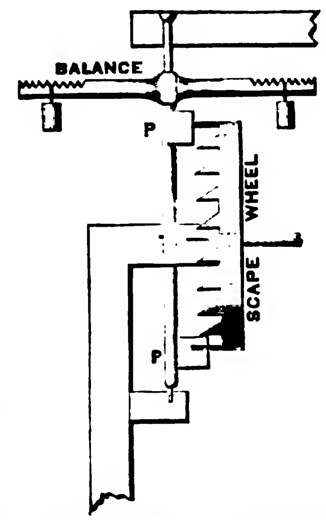
The advance in the art of measuring time may be taken as an index of the progress of man upon the earth. From that early period when time was rudely marked by the alternations of day and night, and the changes of the moon—when the year was vaguely divided into two seasons, cold and warm, which, as Hesiod tells us, were marked off by the coming and going of the birds, down to Professor Rood's recent and wonderful demonstration that the electric spark, which lasts but the twenty-five thousandth of a second, has nevertheless its history—its sequence of phenomena, the first stage of which lasts but the ten-millionth of a second—between these two distant terms of progress there has been a gradual growth of invention and construction, in relation to the arts of time-measurement, which may be taken as exemplifying the general law of advancing civilization.

The accurate time-keeper was the indispensable predecessor of the locomotive, and travel by railway. That it first made possible those rapid movements of multitudes over vast tracts of land and sea, by which people in these latter days have widened their experiences and attained a kind of terrestrial omnipresence, is sufficiently obvious. Yet this is but a small part of the advantages which exact time-measurement confers upon modern society. The first condition of all systematic and concerted human action, of that economy of exertion which is necessary to the highest personal efficiency, and of that synchronism of movement which characterizes modern social life, is the correct indication of time. In the beginning this was not only impossible, but unnecessary. In the primitive state of man, when he had not yet learned to think with accuracy, or to guide his efforts by intelligence, or to combine his exertions with others, the indefinite chronometry of Nature was sufficient for his needs.

Time is measured by any regulated or regularly-recurring series of motions, which may be either natural or artificial. The conspicuous movements of Nature take place in cycles and measured intervals; in fact, all motion whatever is now regarded by the highest scientific minds as rhythmical. The impressive and rapidly-recurring round of changes which constitutes the *day*—the contrast of light and darkness, the sweep of the heavenly bodies across the sky, the recurrence of warmth and cold, and of sound and silence, served as the first natural markings of time. Accompanying this march of the grander phenomena of Nature there was also a chronometry of life—the vital periodicities of waking and sleep, activity and rest, hunger and satiety, the bursting forth and fall of foliage, the opening and closing of flowers, the migrations, cries, and habits of birds, beasts, and insects—all this intermittence of impressions at varying intervals served to give man his first conscious experience of succession, to develop in him the sense of time, and to divide it for his convenience.

But with the beginning of civilization it became necessary to measure time with more accuracy, and art undertook the task. The first artificial contrivances for the purpose were sun-dials, hour-glasses, and clepsydræ With the sun-dial time was measured by the course of a shadow over a scale, and was therefore useless in the darkness of night and in cloudy weather. The hour-glass marked the time by the trickling of fine sand through a small opening between an upper and a lower glass chamber. The clepsydra attained the same result in a similar way by the flow of water. In its simplest form it consisted of an upright cylinder large enough to hold several gallons of water, and having a fine opening at the bottom through which it slowly flowed out. It was of course emptied in equal times, and, being refilled, the successive operations served to mark off the divisions of the day. The Assyrian monarch, Sardanapalus, is said to have had a time-keeper of this description in his palace at Nineveh, and there was one also in every ward of the city. These were all filled at sunrise, and, as soon as they were emptied, at a signal given by a man posted upon a high tower, they were refilled, and a number of heralds sent forth proclaiming the fact through the town, that the inhabitants might regulate their transactions, and know when to eat, to worship, to labor, and to sleep. The intervals between the emptying and refilling in this case, like the rounds of the patrolman, which were also anciently employed to measure time, were termed *watches*.

The flowing water was at length made to turn a wheel, which carried an index around a dial, and thus by the introduction of machinery the hours of the day and the motions of the heavenly bodies were indicated. The simple vessel with an orifice thus gradually grew into a complex mechanism known as the *water-clock*. These contrivances came into extensive use in the East, and served as the measures of time for two thousand years.

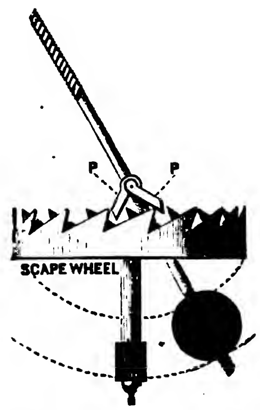


Balance and Escapement of the First Clock.
P P, *Pallets*.

Falling weights were substituted for falling water as the motors of clocks about the eleventh century, the first used being large machines set up in churches and monasteries. The oldest of which the actual construction is preserved, was made by Henry de Vick, a German, and set up in Paris for Charles V. of France, in 1379. It was a thirty-hour clock, with a weight and a train of wheels giving motion to one hand, and the striking part was precisely the same as that still used. The mechanical conception of De Vick's clock was quite similar to that of our modern timepieces. This principle is, that the impelling power stored up in a raised weight or bent spring shall be communicated to a train of wheels, which are set revolving, and that the force or motion shall then be cut up into a succession of minute but equal impulses, which is done by converting a rotary into a vibrating motion. The last and quickest wheel of the train has its teeth so formed that they are alternately caught and escape, and hence the wheel is called the "scape-wheel," and, from its resemblance to a crown, the *crown-wheel*. The bar, or staff, with its projections, which successively catch and release these teeth, is termed the *escapement*, and it is through this that the rotary is converted into the backward and forward movement.

De Vick's old clock had all these parts in a crude form. The oscillating mechanism consisted of a horizontal lever with movable weights, so that the farther out they were hung the slower would be the vibrations. This lever was hence called a *balance*, and the term is still applied to the corresponding part of a watch, although the present watch-balance might be more properly termed a fly-wheel. The escapement, as shown in the figure, consists of the axis of the balance, to which two projections are attached, called the *pallets*, and fixed at such an angle to each other that, as one pallet moves out of the way of a tooth and lets the wheel go forward, the other moves into the space between two teeth, and stops the motion

again. Of course, if there were no check, the weight would run down with an accelerated motion of the train; but, as a tooth of the scape-wheel catches one of the pallets, the movement of the train is arrested and spent in swinging the balance round until the tooth escapes. The train now starts again, but, as a tooth catches the other pallet, its motion is again stopped and expended in arresting the vibration of the balance, and in swinging it round in the opposite direction.

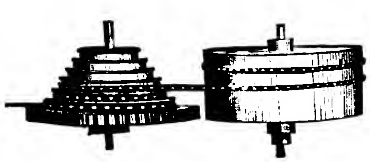


De Vick's Old Balance converted into the Pendulum.
P P, *Pallets.*

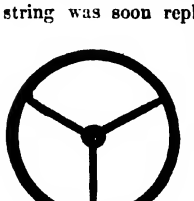
Such was the construction of clocks for three hundred years, when they received their last grand improvement by converting the horizontal swing of the balance into the vertical swing of the pendulum. The accompanying figure shows how, by taking off one of the weights and hanging the balance in an upright position, it becomes a pendulum; and it is claimed by the English that Harris actually made this conversion and constructed the first pendulum-clock for St. Paul's Church on this principle. However this may be, the world credits Galileo with the discovery of that law of the pendulum which made its introduction an epoch in horology, viz., that it swings through unequal arcs, or makes its long and short vibrations in equal times, which is termed its *isochronism*. Galileo is said to have arrived at the principle by noting the vibration of a lamp suspended from the roof of a cathedral, and timing its movements by his pulse. High authorities, however, say that there is no such thing in Nature as *absolute* isochronism, though practically pendulums can be kept vibrating with no greater deviation from it than one vibration in half a million.

The old church-tower clock was the progenitor of the whole race of modern clocks and watches. It was gradually made smaller, and at length became portable with springs instead of weights, and was carried about the person under the name of the *pocket-clock*. This grew into the watch, the earliest of which were large, of an endless variety of forms, without crystals, and either having the face exposed, or with metallic covers perforated over the numbers of the hours on the dial. They opened back and front, had but a single hand indicating neither minutes nor seconds, and were wound twice a day.

The gearing was first impelled, it is said, by a straight spring, but this was soon replaced by the coiled mainspring, a band of fine steel rolled up in a drum, or barrel, and which produced, in unrolling, the effect of the weight. In the case of the clock, the maintaining force, or descending weight, was constant, but in the watch the spring acted with a varying intensity, becoming weaker as it was uncoiled. To equalize its effect, and secure a regular motion, the barrel enclosing the spring was made to act upon the main driving-wheel by means of a catgut string coiled upon a spiral fusee. When, therefore, the mainspring was coiled up and pulled hardest, it acted upon the smaller end of the fusee, and the progressive loss of force in the spring was compensated by an increasing leverage upon the driving-wheel. The catgut string was soon replaced by the fine, strong chain, consisting of several hundred pieces, which is still used in fusee watches, although the date of its introduction is unknown.



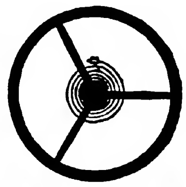
The Fusee. The Barrel.



The Watch Balance.

The balance used was simply De Vick's old clock balance in the shape of a wheel, the weight being accumulated principally in the rim which corresponded to the suspended weights on the horizontal lever.

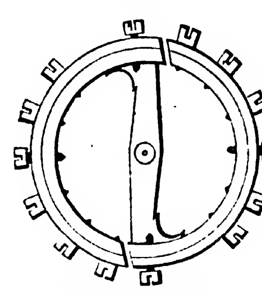
The first important improvement in the old watch, and, indeed, the greatest ever made in its construction, was the application of the coiled *hairspring* to the balance. It effected for the watch what the pendulum did for the clock, and was introduced about the same time, a little over two hundred years ago. Dr. Hooke, who is one of the claimants of the invention, showed that the vibrations of such a spring are very nearly isochronous, and cause the balance to which it is attached to make its excursions in equal time, whatever their length. The vibrations of the old balance depended upon its moment of inertia, and on the force of the train. The inequalities produced by the varying tension of the spring, and the varying friction, reappeared in the varying vibrations of the balance, and the irregular movement of the watch. But this was now avoided by the isochronism of the hairspring, so that, whether the balance moves completely round at each impulse of the scape-wheel when the watch is first wound up, or but half a revolution, as when it is nearly run down, the rate of movement remains the same.



Balance and Hairspring

The next important step of improvement in watch construction was made one hundred and seventy years ago, and consisted in the application of jewels for the bearings of pivots. Precious stones were first drilled for this purpose by Nicolas Facio, a Genevan, but who brought out his invention in England. His contrivance not only reduced the friction of the movements, but gave them such permanence that they would run for generations without perceptible wear. Gems for this purpose are valuable in proportion to their hardness, which decreases in the following order; diamond, sapphire, ruby, chrysolite, aqua-marine, garnet. Many suppose that watch-jewels are made of glass; but this material is too soft and brittle, and is never used, unless it be in the lowest grade of foreign watches made for the "American market."

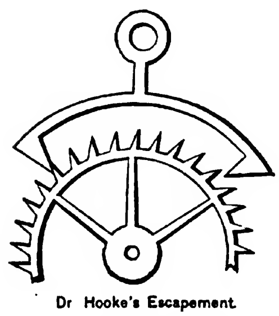
The next epoch in the growth of the watch occurred seventy years later, and still pertained to the balance. It consisted in compensating it for inequalities of temperature. As the watch was gradually brought nearer to accuracy, it was found that fluctuations of heat and cold altered the proportions of the machinery, so as seriously to disturb uniformity of movement. The length and stiffness of the springs were affected; but the main derangement occurred in the balance. With a fall of temperature it contracted, and, vibrating quicker, the watch gained time; heat, on the contrary, expanding it, lengthened the beats, and it lost time. With a change of thirty or forty degrees, the watch might thus vary two or three minutes in a day. It became essential that this source of error should be removed, for the world's commerce depended on it. A ship at sea could find its latitude at any time by observation of the sun or stars; but, to ascertain its longitude, it was necessary to have the exact time. France and Spain had offered large rewards for some way of finding the longitude at sea; and the English House of Commons, through a committee of which Sir Isaac Newton was a member, offered a prize equal to one hundred thousand dollars to whomsoever should improve the chronometer—the marine watch—so that a ship-captain could determine his position at sea within thirty miles of the true place. In 1767, when the offer had been standing fifty years, John Harrison gained the prize by the invention of the compensation-balance. It rests upon the principle that heat expands different metals unequally—brass nearly twice as much as steel, or in the proportion of one hundred and twenty-one to seventy-four. In the compensation-balance the circumference is divided into sections, the ends of which are free, as illustrated in the figure. The outer rim, or tire, is of brass, and the inner rim and cross-bar of steel—these being soldered together, so that one expansion counteracts the other. Cold, contracting the inner, steel rim, would reduce the circumference; but, as it contracts the outer brass rim still more, an opposite effect is produced, the circumference being enlarged. The effect of expansion is checked in the same way. In a well-adjusted watch, whether the temperature rises or falls, these expansions and contractions are so admirably played off against each other, that the balance remains constant through all seasons. Screws set in the rim



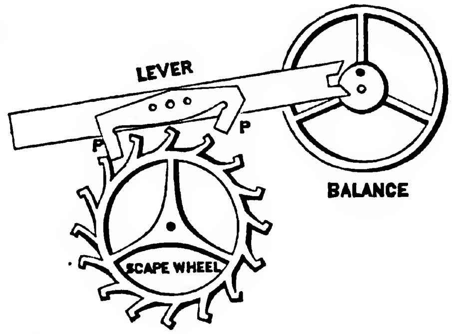
Compensation Balance.

of a balance, which may be altered to various depths and various positions, serve to distribute the weight and poise the balance accurately upon its centre.

The last of the series of important improvements which have brought the watch to its present perfection pertains to the escapement, which transforms rotary into vibratory motion. The accompanying woodcut shows a common form of it, and recalls what we have all seen in the old caseless Dutch clocks. One would hardly think, from its simple and innocent appearance, that it had been the torment of mechanics and mathematicians for five hundred years. Yet it existed in the first clock, and its first construction and adaptation, no doubt, gave old De Vick many a hard headache; while the subsequent history of the variations, experiments, and theories of escapements, would make a cyclopædia. That which has been settled upon as the most perfect is known as the "patent-lever escapement," or the "detached escapement;" and this particular form of it is due to the joint and successive labors of the most eminent watchmakers of the last century—Berthoud, Le Roy, Earnshaw, Graham, and Mudge—all men of genius, and who made it a life-study. The combination which has been selected by the American Watch Company, as nearest perfection, is represented in the subjoined diagram. The bar, or "patent lever," to which the pallets P P are attached, turns upon a centre-pin, so that the ends of the lever move backward and forward through small arcs, as the pallets are alternately released from the scape-wheel. One end of the lever has a little nick in it, which, as it passes backward and forward, catches a pin upon the balance, and throws it right and left. As the lever, for example, moves to the left (see diagram), one of the pallets catches a tooth of the scape-wheel, and stops the train; at the same time the balance is thrown round, so that the pin passes out of the nick, and the balance swings free to the extent of the impulse—that is, it is *detached* from the lever. As it swings back under pressure of the hairspring, the pin catches in the nick again, and, moving the lever back, unlocks the pallet, when instantly the other pallet is caught by another tooth, and the lever throws the balance the other way. The balance, therefore, in its isochronal swing, throwing the lever this way and that, and alternately locking and unlocking the teeth of the scape-wheel, determines the rate of movement of the train.



Dr Hooke's Escapement.

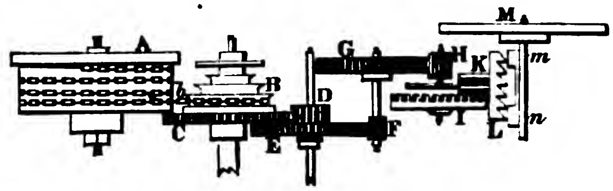


The "Patent Lever," "Detached Lever," or "Detached Escapement."

P P, *Pallets.*

When it is desired to alter this rate of movement—that is, to "regulate" the watch—we have to regulate the regulator, which is usually done by altering the length of the hairspring. Shortening the hairspring is like shortening the pendulum—all the beats are made quicker; if lengthened, they are all made slower. It is obvious, therefore, that the regulation of a watch is a matter of great delicacy, as whatever change we make in one beat reappears in every beat, and is multiplied three million times in the course of a week.

The accompanying cut represents the train of an English verge watch, the frame-plates being omitted, and the face-side turned downward. The vertical watch (not the detached lever) is selected because it best shows the relations of the working parts. A is the *barrel* containing the spring. B is the *fusee*, to which the key is applied in winding, and which is connected with the barrel by the chain *b*. C is the *fusee-wheel*, called also the *first* or *great wheel*, which turns with the fusee, and works into the pinion D, called the *centre-wheel pinion*. This



Movement of the Common Vertical Watch.

pinion, with the *centre-wheel*, or *second wheel*, E, turns once in an hour. The centre-wheel E works into the *third-wheel pinion* F; and on the same arbor is G, the *third wheel*, which drives the fourth or *centrate-wheel pinion* H, and along with it the *centrate wheel* I. The teeth of this wheel are placed at right angles to its plane, and act in the pinion K, called the *balance-wheel pinion*, L being the *balance-wheel*, *scape-wheel*, or *crown-wheel*. The scape-wheel acts on the two *pallets*, *m* and *n*, attached to the *verge*, or arbor, of the balance M, which regulates the movement.

The exquisite working of a well-constructed watch is a matter of interesting reflection. By half a dozen turns of the key a modicum of force is stored up in the spring, and, in the running down of the train and the reaction of the hairspring against the mainspring, that force is cut up into half a million little beats, which are so exactly equal that in the most perfect form of the mechanism it deviates from the uniform motion of the stars but the fraction of a second in a year. There can surely be no loss or destruction here of even the most infinitesimal amount of force—a fact which ought long ago to have suggested the principle of the "indestructibility of energy." We lend to our watch each morning a little instalment of that vital movement which we ourselves borrow daily from the sun. One portion is spent in overcoming the friction of the train, and another portion in the percussion of the pallets, which sets the air to vibrating, and produces the ticking sound; but the force, though infinitely disintegrated, does not come to nothing—it is all converted into heat. And thus the solar heat, after undergoing a series of organic transformations, is deposited as mechanical force in the watch-spring, and is at last converted back again into heat and radiates away into space. The daily running down of the watch, therefore, symbolizes that mighty dissipation of solar energy and running down of the solar system which is now inferred to be a consequence of the laws of physics.

We have seen that the watch has been brought to its present state in a gradual way. A little examination will now show that this advance has been governed by a definite and important principle—a regular law of growth or development. But in what sense, it will be asked, can a watch be said to *grow?*

Those who have studied the phenomena of life tell us that growth consists in a change from the uniform or homogeneous state of the germ to the heterogeneous condition of the organism. The change, by which unlike parts become different and distinct, is called *differentiation*, and the further change, by which unlike parts become more closely dependent, or unified, is termed *integration*. Hence, as we ascend in the scale of development, there is increasing differentiation and a higher integration. Now, we have reason to think that this is a great principle of Nature, not limited to bodily growth, but applying equally to society, to art, and to industry. Both the watch and watch-making industry furnish striking and instructive confirmation of this statement.

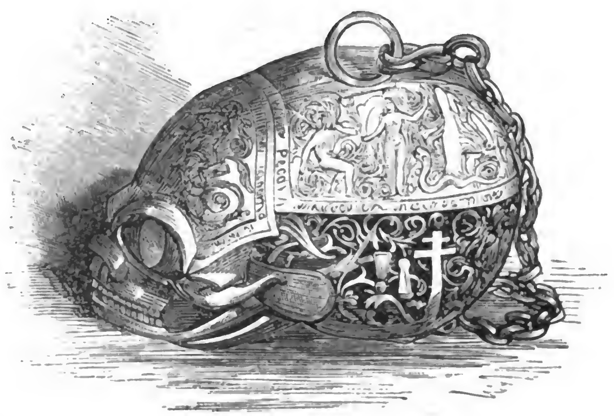
In the infancy of the art, when the watch was made by hand and by one man, the idea of a time-keeper was but imperfectly differentiated; that is, it was mixed up in the artisan's mind with all sorts of foreign and fantastic notions. Instead of a mechanism simply to measure time, the watchmaker was constantly striving to produce something novel, curious, and astonishing. The forms and sizes of watches were innumerable. Some were as large as saucers, and others were of the most marvellous minuteness. One is still preserved in a Swiss museum but three-sixteenths of an inch in diameter, set in the top of a pencil-case, which indicates the days of the month, as well as the hours, minutes, and seconds. In form they took the shape of the pear, the almond, the melon, the tulip, the shell, the bird, the cross, the skull, the coffin, etc., and they were inserted in snuffboxes, finger-rings, shirt-studs, bracelets, and saddles. A bulky book has lately

been published on the curiosities of watches, which is little else than a record of the whimsicalities and futile ingenuity of watchmakers in accordance with the capricious and fantastic taste of the times. The notion of a *time-keeper*, at length emerged into distinctness, became gradually predominant in the maker's mind, and determined the watch to its present settled form.

The Watch as a Double Cross.

But even when these external eccentricities and extravagances had been largely got rid of, the inner construction remained complicated with all manner of objects besides simple time-keeping. There seems to have been a phase of the human mind when mechanical invention was subordinated to the production of wonders; and ingenious men gave their lives to the construction of the most intricate and useless machines, such as artificial, automatic animals, which should simulate the actions of living creatures. This singular ambition long displayed itself in watchmaking. Watches, striking the hours and quarters, were made with the most elaborate ornamental openwork for the emission of sound. Musical watches that played tunes, and speaking watches that imitated voices, were produced as expensive toys for the rich; chimes, alarums, stops, self-winders, and repeaters, and watches indicating the day of the month and the changes of the moon, continued for a long time to be exploited by ingenious makers, although all these appendages were drags upon the works, and detracted from the simple, essential purpose of the mechanism. It was only by that gradual differentiation of human thoughts and feelings, by which the conception of *utility* grew into greater distinctness, that there was a corresponding differentiation of the watch as a simple *time-keeper*, and a concentration of effort to perfect this object alone. The appendages were gradually abandoned in watches of the best construction, and, when the American Watch Company resolved to transplant this ancient industry of Europe to the soil of this country, and establish it upon a new method, such an enterprise was made possible only because the watch, reaching its last stage of differential growth, had become simply a *time-keeper*, and because the idea of the useful and serviceable had become so clear and strong in the American mind as to assure its general appreciation.

Yet the watch, although completely differentiated in purpose, was not completely unified, or integrated, as a mechanism. Every essential step of invention from the outset had tended to bring the parts into more close and perfect dependence, so as to execute its design with the utmost precision. Each incidental and complicating part, and each liability to error or failure that had been eliminated, was a step of growth toward completer integration and more perfect unity of the mechanical structure. But when the American Watch Company entered upon the manufacture, they found that the watch had been by no means reduced to its last degree of simplicity. The English movements of the highest character, although performing well, were still exceedingly complex, and, as the risks of derangement in any machine are, other things equal, in the ratio of its complexity, it was in a high degree desirable to relieve the contrivance of every part not absolutely essential to its purpose. Determined to prune the watch of every superfluity, and bring it at once to the last term of simplicity, consistent with its design, the engineers of this company at once struck away the fusee, chain, main-wheel, and the retaining power which those parts necessitated. Surprising as it may seem, by this bold stroke more than *three-fourths* of the pieces composing the watch were swept away. The chain alone consisted of several hundred pieces, so that, of the eight hundred parts of the first-class English watch, but one hundred and fifty-eight remain in the movement adopted by the American Company.



The Watch as a Skull.

This was a most important step, as the advantages of removing the fusee and its complex appendages were numerous and important. In the first place, the watch could be produced at much less cost. The chances of failure from flaws in the workmanship were, besides, greatly reduced. The friction of the train was diminished by one half, so that thinner and lighter springs could be used, which are more lasting and equable in their action. Moreover, the parts got rid of were the most difficult and expensive to repair. When brought to the supreme test, that of "performance," the simplified American watch, furthermore, bears comparison with any other; the wide and free motion of the isochronous balance proving quite sufficient to govern and equalize the movement.

That the English should still retain these superfluous parts in their watches, is simply due to their conservative habits, as their highest authorities have pronounced against them. Still, there are Englishmen who can appreciate the best thing, regardless of national prejudice. Mr. Herbert Spencer, for example, a keen and inexorable critic, regulates his life by an American integrated watch; and, under the test of constant competition with the finest English time-keepers, he bears cordial testimony to the precision and perfection of its performance. The perfected American watch, in the simplicity, accuracy, permanence, and cheapness of its construction, represents the highest stage in the growth of the watchmaker's art; it is the result of a great law of advancing industry, the working of which will be traced in another article.

THE THREE BROTHERS.

BY MRS. OLIPHANT, AUTHOR OF "THE CHRONICLES OF CARLINGFORD," "THE BROWNINGS," ETC.

CHAPTER XLIV.—THE FALLING OF THE WATERS.

THE readers of this history must be prepared to pass over an interval of something less than seven years, from the end of the last chapter. I allow that it is a most undesirable break, but yet it has been involved from the beginning as a necessity of the narrative.

Nearly seven years had elapsed, since Mr. Renton's death, at the moment when we again approach Renton Manor. He died in September, and it was the beginning of August when Mrs. Renton received a note from Mr. Ponsonby, the lawyer, announcing his intention of arriving at the Manor the next day. Mrs. Renton had not improved much in health, but she had laid aside her mourning, and wore gray and violet, and pretty caps, once more. Her existence had known very little change during all these years. Now and then the tonics had been changed, and she had substituted for a whole year the Revalenta Arabica for the arrowroot; but the difference was scarcely